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Abstract

S-BPM targets Business Process Management and has been applied in various business domains to model business processes and implement workflow support. This chapter investigates S-BPM's capabilities to support workplace and process design as well as process execution in production companies. Thereby, industrial capabilities of S-BPM are structured along the three dimensions of socio-technical systems which need to be considered for Industry 4.0 developments. Technological capabilities address the ability to integrate processes on different automation levels (planning, monitoring, real-time execution, etc.). Organizational capabilities discuss the potential of subject orientation for organizational development, and human capability development investigates how humans in production companies could be supported when involving them in workplace (re)design.

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3.1 S-BPM's Technological Capabilities

Subject-oriented Business Process Management (S-BPM) represents a generic approach to modelling, execution and improvement of business processes, with a particular focus on the involvement and empowerment of the people in the process. S-BPM has been applied in many business domains for a variety of process applications, such as “service order and delivery in the banking area”, “management of the development and maintenance of complex processes” or “incident management” (Konjack 2010; Nakamura et al. 2011; Walke et al. 2013). These application cases have focused on providing workflow support for SMEs and large companies.

However, business processes are just one part of the process landscape in production companies; and while business processes are certainly important for these companies, they are not considered to be “core” processes. It is the physical processing and movement of materials on the shop floor, with associated manual or automated activities, representing the predominant concern of production managers and production workers alike. Therefore, the application of S-BPM in the production domain requires expanding the scope of process management. Thereby, not only business, planning and logistics but also shop-floor activities need to be captured.

Processes in production enterprises have traditionally been represented at different levels of abstraction and granularity. A well-known framework defining these levels is the IEC 62264 control hierarchy depicted in Fig. 3.1. It comprises four levels: Field Instrumentation Control (Level 1), Process Control (Level 2), Manufacturing Operations Management (Level 3) and Business Planning and Logistics (Level 4).

As these levels impose distinct requirements on processes with respect to real-time processing, data storage, safety and security, the development of models and systems at each level has been undertaken rather independently. This has resulted in poorly integrated applications especially between Low-Level Control (LLC, i.e. Levels 1 and 2) operating in real-time and High-Level Control (HLC, i.e. Levels 3 and 4) operating in non-real time. Systems developed for LLC include Programmable Logic Controllers (PLCs), and systems for HLC include ERP, MES and BPM systems. The vertical integration of processes across the different levels and systems has been considered essential, since none of the processes of an enterprise operates in isolation. It is rather triggered by others and, vice versa, other processes rely on the output of another process. For planning, executing and monitoring this network of processes effectively and efficiently, all processes need to be seamlessly integrated.

A major objective of the EU-funded project “Subject-Oriented for People-Centred Production” (SO-PC-Pro) has been seamless process integration via S-BPM. The SO-PC-Pro approach for vertical integration is depicted in Fig. 3.2. It is based on using subject-oriented process models as a uniform representation of processes at all levels of the IEC 62264 control hierarchy, including HLC and LLC processes. The theoretical feasibility of this approach has already been demonstrated by Müller (2012). Data between processes at the different levels may be

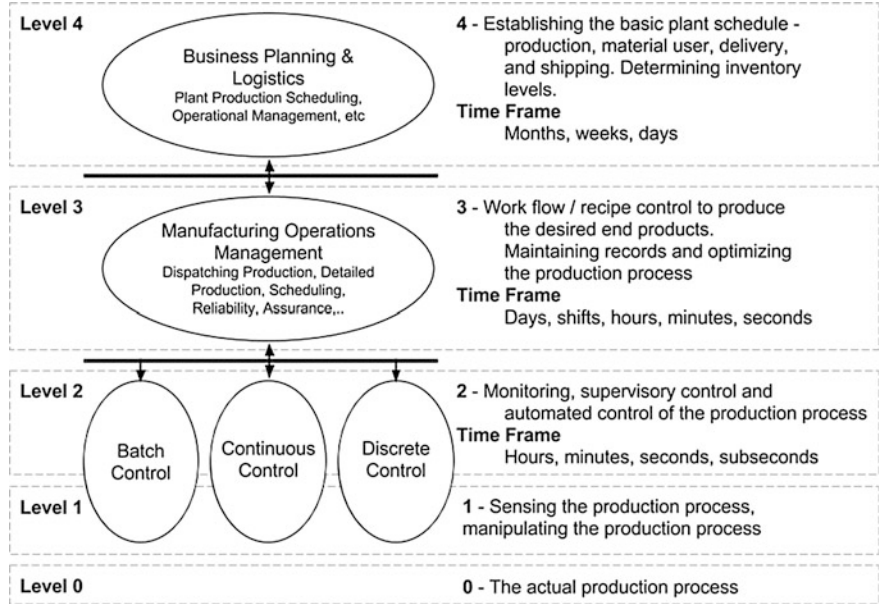


Fig. 3.1 The IEC 62264 control hierarchy (adapted from IEC 62264-3 © 2007 IEC—All rights reserved)

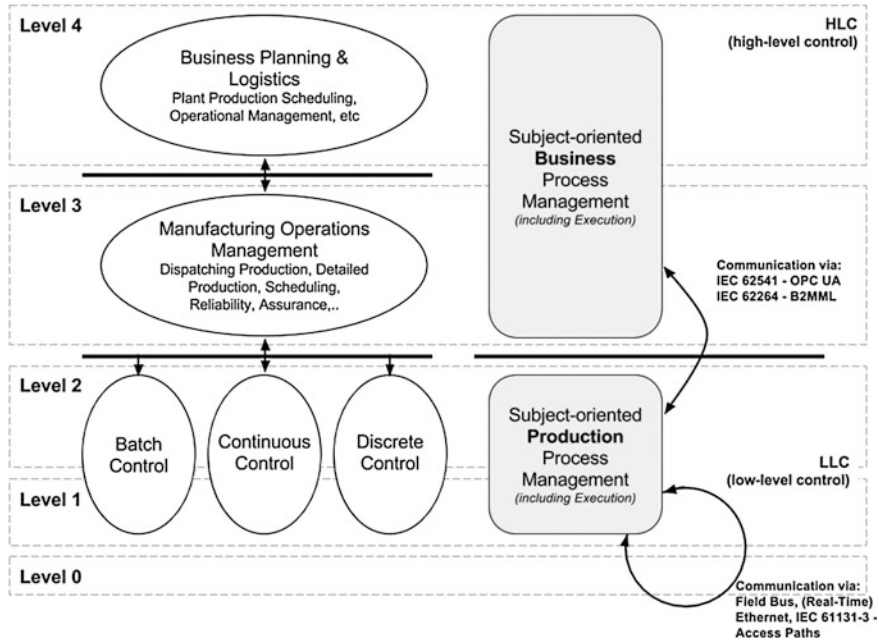


Fig. 3.2 Vertical integration of processes based on S-BPM and existing data standards including OPC UA (extended based on IEC 62264-3)

exchanged using existing automation standards, including OPC UA (IEC 62541) and B2MML (IEC 62264). OPC UA is a communication protocol that is implemented in most modern PLC environments. OPC UA includes specifications of semantic data models that can be exchanged via web services or binary protocols.

In the course of the SO-PC-Pro project, interfaces for an S-BPM-based process integration have been developed and tested. The developments are based on the Metasonic Suite software for modelling and executing S-BPM processes. They comprise:

- A B2MML interface
- An OPC UA interface
- An extension for transforming S-BPM behaviours to executable IEC 61131-3 conform PLC code

3.1.1 Exchanging Process Data via B2MML

B2MML (MESA 2013) stands for “Business-to-Manufacturing Markup Language” and provides a vendor-, platform- and company-independent format which allows handling the data of a process to be exchanged between Level-3 and Level-4 applications (Scholten 2007; Gifford 2011). B2MML represents an XML implementation of the ISA-95 (IEC 62264) standard and consists of five parts:

1. Models and terminology
2. Object model attributes
3. Activity models of manufacturing operations’ management
4. Object models and attributes for manufacturing operations’ management integration
5. Business-to-manufacturing transactions defining transaction verbs for data messages, e.g. cancel, confirm, change, get or show

In the S-BPM methodology, individual chunks of functionality are represented as so-called subjects that are interlinked via messages. Every subject encapsulates its individual behaviour specification defining sequences of tasks that produce, consume and/or modify data provided by specific applications such as Enterprise Resource Planning (ERP) systems and Manufacturing Execution Systems (MES). The exchange of data between the different applications is thus mediated by communicating subjects, providing the “glue” for integrating applications both vertically (e.g. across an MES on Level 3 and an ERP system on Level 4) and horizontally (e.g. across an ERP system and a project planning tool, both of which are on Level 4). The interfaces between the S-BPM process and the specific applications are defined using B2MML, as shown conceptually in Fig. 3.3.

The integration via S-BPM processes can be modelled and executed using the Metasonic Suite. This tool provides a number of ways to establish and configure

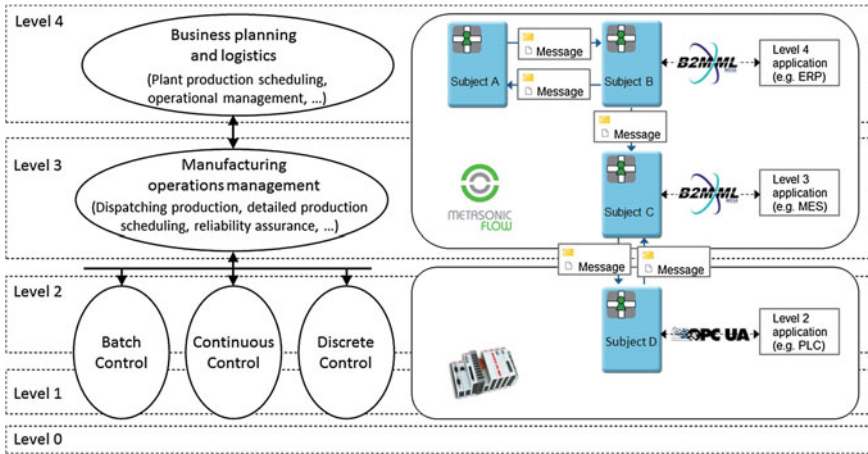


Fig. 3.3 S-BPM as the glue for integrating processes across Levels 2 and 3 (OPC UA interface) and Levels 3 and 4 (B2MML interface) in the IEC 62264 control hierarchy

mappings between the data objects stored in the Metasonic Suite and the data structures provided by external applications. However, as currently there is no support for common data standards, the definition and maintenance of these mappings is usually a tedious effort. This hampers the agility needed in modern factories, as the mappings need to be reconfigured every time a new application is integrated or a change occurs in its data requirements. Using the B2MML standard as a basis for defining the mappings of the Metasonic Suite and B2MML-compliant applications helps overcoming this challenge.

On a technical level, a B2MML interface has been implemented in Metasonic's S-BPM process modelling suite by means of two extensions:

- Ext 1.** An import wizard for selecting the B2MML schemas needed in a particular process model and transforming them into data objects
- Ext 2.** A graphical user interface (called "refinement template") for configuring the exchange of data objects with B2MML-compliant external applications

These features support a best practice related to the B2MML application for Level-3 and Level-4 data integration. This best practice means to first "identify[...] the context and content of the information that needs to be exchanged" (Pipero and Manjunath 2006). These aspects are commonly provided by process models, in terms of task structures, communication between process participants and the data objects handled in the process. Thus, connecting B2MML with an S-BPM process (and workflow engine) requires the following two steps:

1. Generate S-BPM data objects (called "business objects") according to the B2MML schemas relevant in the respective process (by applying Extension 1 given above)

2. Configure the exchange of the data objects (read/write) between the S-BPM process and the external applications involved (e.g. MES, ERP) (by applying Extension 2 given above)

Business-to-manufacturing integration is a challenge since the early days of ERP and MES systems (Gifford 2011, p. 184). The standardization efforts related to B2MML target the reduction of time spent, costs and increase of successful ERP and MES system integration. However, Gifford (2011) states that Level-4 and Level-3 integration projects initially require to “understand and document the business reasons for the integration” (e.g. gaps in information exchange, media discontinuity). Furthermore, the selection and definition of the processes involved is vital.

In general, Level-4 and Level-3 integration projects include one of the following process types (cf. Gifford 2011, p. 186):

Production order management; Production response management; Maintenance operations management; Laboratory operations management; Warehouse, tank farm, and other inventory operations management; Operations capacity management; Receiving management; Shipping management; Manufacturing master data management (MDM); Key performance indicators (KPI) and overall equipment effectiveness (OEE) calculation, monitoring and management.

The implementation of such integration projects typically requires a middleware that enables the interaction, for example through schema conversion, data conversion or intelligent routing (cf. Scholten 2007, p. 190). The developed B2MML prototype for S-BPM enables case-based modelling and execution of the behaviour of such an S-BPM based middleware. The middleware behaviour can be shown using the S-BPM interaction diagram in Fig. 3.4.

Depending on the individual application case the integration solution may differ in terms of relevant B2MML data structures to be exchanged, and internal subject behaviours of the ERP/MES subjects. Sample cases for enabling the interoperability of different existing ERP systems and MES are (cf. Vieille 2012):

- Case 1: ERP and MES are not IEC 62264 compliant
- Case 2: ERP is IEC 62264 compliant
- Case 3: MES is IEC 62264 compliant

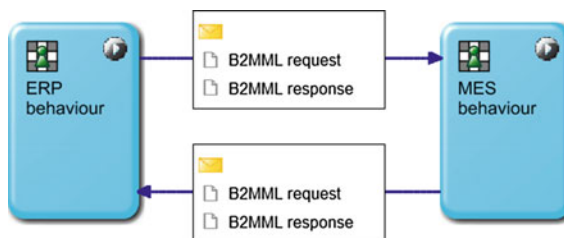


Fig. 3.4 Generic S-BPM model for ERP and MES behaviour integration via B2MML

- Case 4: ERP and MES speak B2MML
- Case 5: B2MML mapping

For each of the cases relevant processes and data need to be defined at first. Based on the selection further integration steps can be taken. In *Case 1* neither the ERP system nor the MES apply B2MML. However, B2MML may act in this case as intermediary language between given ERP and MES elements. In such a situation, the modelling approach could be structured as follows:

1. Select relevant B2MML elements for actual integration case and create a corresponding intermediary business object (BO) in the Metasonic Suite.
2. Model the ERP behaviour in Metasonic Build and fill the defined B2MML object with the corresponding information from the ERP system (ERP -> B2MML mapping), e.g. fill the B2MML BO via Metasonic's existing "DBReader" refinement template with data from the ERP database, fill via data requested from a web service
3. Model the MES behaviour in Metasonic Build and apply the B2MML business object when exchanging data with the MES, e.g. via a MES web service, MES specific messages. Since the MES is not B2MML enabled in this case, additionally, a transformation is required from B2MML to a MES interpretable format

In *Case 2 and 3*, either the ERP or the MES is able to receive/send B2MML messages. For the system not being B2MML compliant, a transformation needs to be implemented within the S-BPM middleware (compare Step 2 and 3 of Case1).

Case 4 describes a situation in which both systems are B2MML compliant and could exchange B2MML data directly. In such a case S-BPM might act as an intelligent router. However, due to possible, custom B2MML extensions or supported transaction, errors might occur in the communication. Therefore, *Case 5* is a more convenient solution, which considers individual XML extensions and maps the custom XML extensions to B2MML messages. Here the mapping functionality needs to be implemented by the subject (ERP or MES) providing the extensions. In general, the mapping may be defined in S-BPM within refinements of function states by writing Java code to be executed at runtime.

In addition to Level-4 and Level-3 integration support, S-BPM can be applied to support the integration of processes across the Levels 3 (Manufacturing Operations Management) and 2 (Process Control) via the OPC Unified Architecture (UA).

3.1.2 Process Communication via OPC UA

OPC UA represents a standardized communication protocol (cf. IEC 62541) enabling the vendor- and platform-independent communication within and between Level-1 and Level-2 processes executed by Programmable Logic Controllers (PLCs). To enable runtime communication among Level-3 and Level-2 processes,

the data exchanged need to be defined according to the OPC UA standard. As this needs to be done at design time (i.e. before the actual execution of the processes), the process modelling editor Metasonic Build has been used as a basis for a OPC UA data definition prototype. Specifically, a graphical user interface as part of this editor has been developed to guide the S-BPM process modeller through the steps required when specifying OPC UA interfaces.

The basic features of the interface have been derived from the structure of the OPC UA standard (IEC 2008). OPC UA applies the client–server concept to implement the interaction between different communication partners, e.g. a workflow engine and a shop-floor PLC. To allow requesting services provided by an OPC UA server or within a network of OPC UA servers, OPC UA defines an Address Space model. In such an Address Space an OPC UA server defines which contents (i.e. nodes representing objects, variables, methods etc. related to dedicated objects) are visible/editable for clients. Servers also allow clients to monitor attributes and events on the server. Each client can subscribe to the attributes and events it is interested in and will then be notified accordingly.

Figure 3.5 shows the basic functions of the OPC UA refinement template using a schematic representation for the interplay between the behaviour of the “PLC” subject in the Metasonic Suite and a PLC addressable via an OPC UA server. The refinement template allows (1) configuring the endpoint of the server, (2) configuring the relevant node (e.g. variable, method and event), (3) reading/writing variables from/to business objects, (4) invoking methods on the server and (5) subscribing to data changes or events provided by the server.

The concrete OPC UA refinement template shown in Fig. 3.6 allows (i) reading values from a PLC and storing them in a business object, and (ii) writing concrete values of a business object to variables of a PLC. The template thus facilitates configuring the concrete OPC UA server endpoint that provides the desired

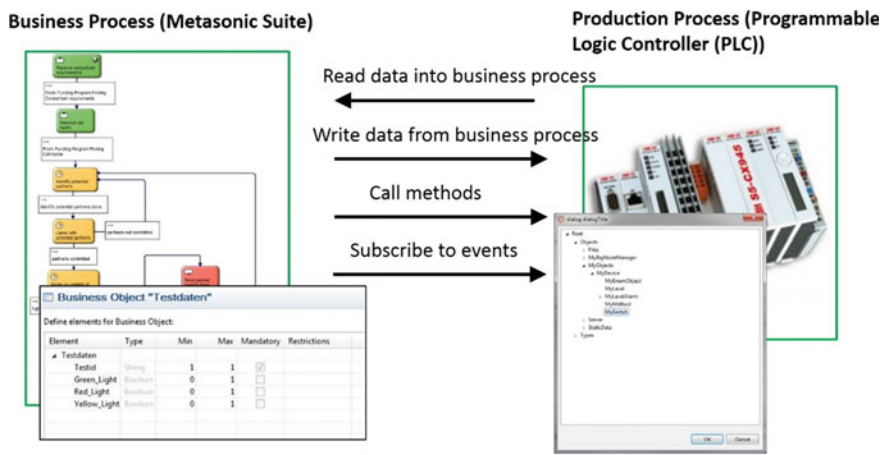


Fig. 3.5 Basic functions of the OPC UA refinement template

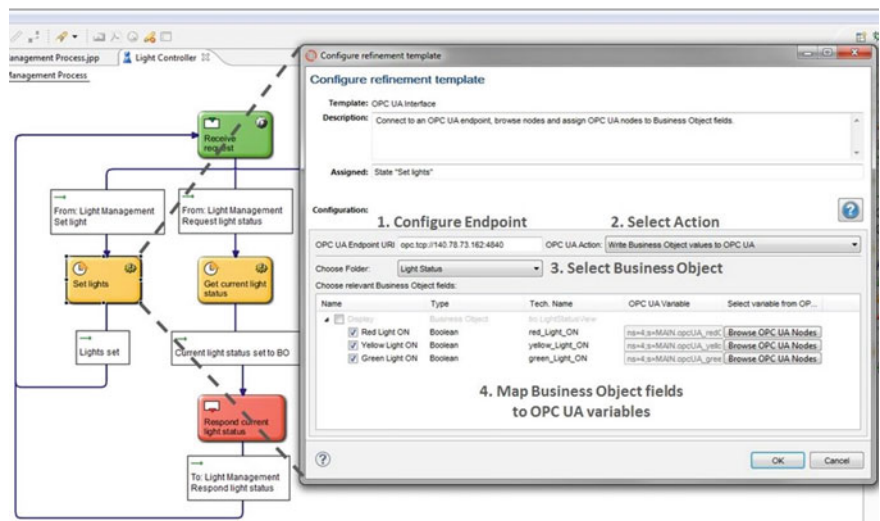


Fig. 3.6 Refinement template for reading/writing values from/to an OPC UA server variable

variables. Furthermore, one needs to choose the action and the relevant business object before mapping variables to each other. The refinement template shown in Fig. 3.6 allows mapping multiple PLC variables to different fields of business objects. It is associated with the function state “Set lights” within the SBD of the “Light Controller” subject in a lighting control process.

3.1.3 Executing S-BPM Models in Real Time via IEC 61131-3

The B2MML and OPC UA interfaces allow using S-BPM as the glue for integrating processes at any location of the vertical control hierarchy. This is depicted conceptually in Fig. 3.3. Current implementations of this approach are based on using Metasonic Flow as the workflow engine that controls the execution of all subjects in the process. This has an important limitation: The execution times of subjects located at Levels 1 and 2 are too slow to meet the “hard” real time constraints of many control tasks, because Metasonic Flow was designed for office-based processes where time is usually measured in days, hours and minutes—not in milliseconds or microseconds, as typically being the case in automated factory processes. To fully apply the S-BPM approach to production processes, a different workflow engine is needed that is capable to execute real-time behaviours of S-BPM processes.

Today only Programmable Logic Controllers (PLCs) can execute real-time control tasks on the shopfloor. However, PLCs are not commonly thought of as “workflow” engines because they deploy specialized programs (often based on automation standards defined in IEC 61131-3) rather than general workflow

descriptions. In the SO-PC-Pro Project, a prototype of a real-time workflow engine resulting from the transformation of S-BPM workflows into IEC 61131-3 programs that can be read and executed by PLCs has been developed. Thus, S-BPM behaviour models can be used to describe PLC behaviour similar to IEC 61131-3 Sequential Function Charts, and to map and deploy them to concrete PLCs.

The ability to transform S-BPM into IEC 61131-3 and vice versa is based on the close similarity between the Abstract State Machine (ASM) formalism of S-BPM (Börger and Fleischmann 2015) and the Sequential Function Charts (SFCs) language of IEC 61131-3. A set of mappings between individual S-BPM constructs and IEC 61131-3 constructs has been developed in the SO-PC-Pro project and encoded in the Metasonic Build functionalities. A conceptual model for the S-BPM based PLC model creation and deployment is given in the following figure. It depicts build-time dependencies (PLC logic export/import; PLC behaviour deployment) as well as run-time dependencies (Metasonic flow may access PLC logic via OPC UC Server) (Fig. 3.7).

Summarizing, the technical developments in the SO-PC-Pro project include interfaces for S-BPM that connect different levels in the IEC 62264 control. These interfaces comprise:

- OPC UA interface for integrating processes across Levels 2 and 3
- B2MML interface for integrating processes across Levels 3 and 4
- Mapping S-BPM onto IEC 61131-3 to reuse S-BPM behaviours and deploy them on PLCs for real-time execution

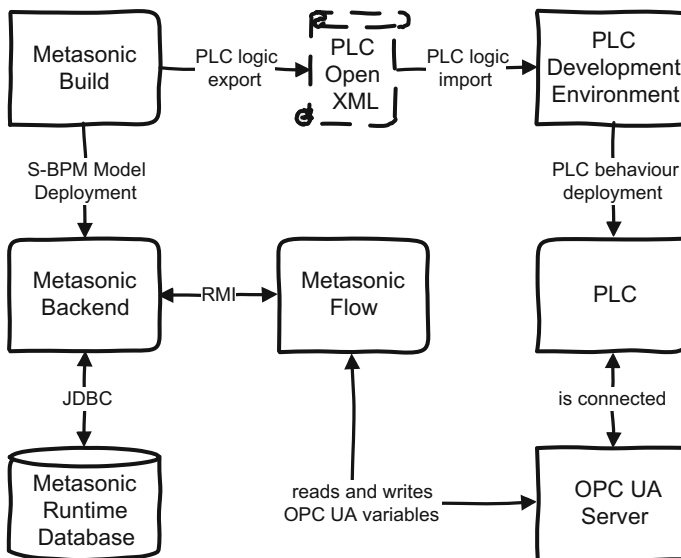


Fig. 3.7 Conceptual mapping architecture

The application of the above given technical developments will be illustrated within the case studies presented in the subsequent chapters. Especially, within the lot-size 1 case the focus has been seamless integration. Thus, this case will describe the application of the interfaces.

3.1.4 S-BPM as Communication Model for Process Integration

Aside to structuring the developments along the ISA 95 automation pyramid, an alternative point of view may be taken as described below. The shape of the IEC 62264 model reflects two distinguishing characteristics. First, this automation architecture is strictly hierarchical. Systems at the same hierarchical level share similar functions and need to satisfy similar constraints regarding real-time processing, data storage, safety and security. Second, the automation pyramid reflects the amount of data being processed at the different levels. Towards the bottom end (or wider end) of the pyramid large amounts of raw (sensor) data are produced and handled, while towards the top end (or narrower end) of the pyramid the data become more condensed and less frequently exchanged (Vogel-Heuser et al. 2009).

The strictly hierarchical structure with clearly defined concerns at each level had a strong impact on the vertical connectivity of many automation systems, in that, individual components within one level were developed to exchange data only with components of adjacent levels. A number of standard protocols were defined to establish the necessary communication layers for these exchanges.

Over the past 25–30 years, a number of changes in technology and production organization have occurred that break with the foundational assumptions of the traditional automation pyramid (Vogel-Heuser et al. 2009). At the bottom end of the pyramid, field devices became computationally more powerful and intelligent, with a new range of communication capabilities that allow for modular organization and decentralized control of production processes (Vogel-Heuser et al. 2009; Mendes et al. 2012). Such smart devices are today called cyber-physical systems (Kagermann et al. 2013) and compose what is often called the industrial Internet of Things (IIoT) (Haller et al. 2009). Communication between devices is no longer restricted to adjacent levels but can occur anywhere across the hierarchy. A similar trend can be observed towards the top end of the automation pyramid, where there is increasing interest in decentralized approaches to business process management such as agent-based and service-oriented architectures (Sinur et al. 2013; Cummins 2009).

To account for these changes in the production industry, more recently a new model for automation was proposed (Vogel-Heuser et al. 2009): the “diabolo” model, as shown in Fig. 3.8. Diabolo is an acronym for “Distributed Information Architecture to Bolster Lifecycle Optimization”. It also reflects the double-cone shape of the model.

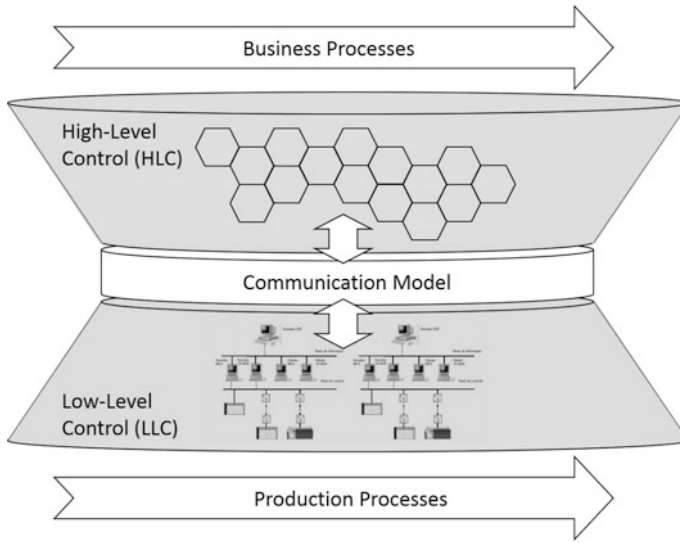


Fig. 3.8 The diabolo model of modern automation systems (adapted from Vogel-Heuser et al. 2009)

In the diabolo model, the four hierarchical levels are collapsed into just two:

- *High-level control* (HLC, upper cone in Fig. 3.8) is composed of Levels 3 and 4 in the traditional automation pyramid. The hexagons in the figure represent the interconnected process functionalities typically found in production management, including common Level-3 functions such as work order management, quality management and maintenance management (McClellan 1997; Vogel-Heuser et al. 2009), and Level-4 functions such as planning, logistics and business process management.
- *Low-level control* (LLC, lower cone in Fig. 3.8) is composed of Levels 1 and 2 in the traditional automation pyramid. As indicated in the figure, the various field devices and PLCs remain hierarchically structured to meet real-time and other requirements specific to process control in physical production environments.

The two levels are vertically integrated by a communication model that provides a central interface for all cross-level exchanges of information. These exchanges may involve any field device within the LLC level, including sensors and actuators. Having a central interface is convenient, as it avoids having to maintain potentially large numbers of point-to-point interfaces.

The increasing modularization and distribution of processes at both HLC and LLC levels can be conceptualized using the idea of partial diabolos (Vogel-Heuser et al. 2009). Every diabolo represents a “module” (that may be composed of other modules) that is functionally and/or structurally (i.e. by implementation as a

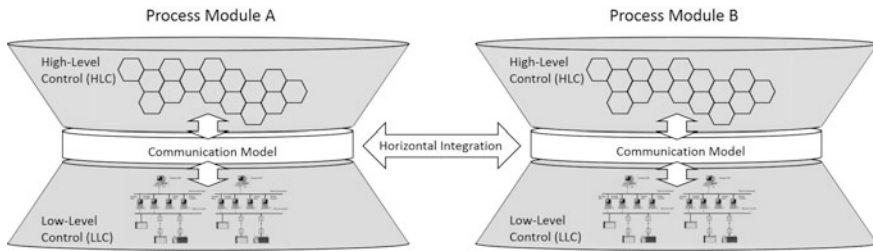


Fig. 3.9 Horizontal integration of multiple diabolos via the communication model

separate component) distinct from other modules. As shown in Fig. 3.9, partial diabolos are interconnected via the horizontal integration of their communication models. This is the foundation of the notion of “plug-and-produce”: the model-based reconfiguration of automation software to adapt to changes in products and production processes (Niggemann et al. 2015).

Subject-oriented business process management fulfils essential criteria for such a communication model stated in recent literature (Vogel-Heuser and Feiz-Marzoughi 2013; Keddiss et al. 2014):

- S-BPM includes modelling data structures in terms of so-called business objects (Fleischmann et al. 2012)
- S-BPM allows mapping data objects between different external systems by means of refinements (Fleischmann et al. 2012; Kannengiesser et al. 2016)
- S-BPM describes process logic together with the data mappings (Fleischmann et al. 2012; Kannengiesser et al. 2016)
- S-BPM has a well-defined formalism that allows instant execution by a run-time environment (Fleischmann et al. 2012; Börger and Fleischmann 2015)
- S-BPM provides generic constructs that enable modelling business processes as well as physical production processes (Müller 2012)
- S-BPM supports the creation of individual views for different systems and users (Fleischmann et al. 2012)
- S-BPM uses a data-centric coordination concept that allows for loosely coupled, flexible system architectures (Meyer et al. 2011; Kannengiesser 2015)
- S-BPM has a minimal set of modelling constructs, facilitating understanding by stakeholders with different educational backgrounds (Fleischmann et al. 2013)

The overall concept of using S-BPM as the basis of a communication model in the automation diabolos is shown in Fig. 3.10. Every system is represented as a subject that encapsulates its behaviour and data structures. Subjects coordinate the execution of their behaviours through message passing, establishing a decentralized process architecture. Subjects may encapsulate not only individual systems but also systems of systems. For instance, “Subject F” in Fig. 3.10 represents a whole process module (“Process Module C”). As indicated in the figure, that module may use a non-S-BPM based communication model, such as one based on UML

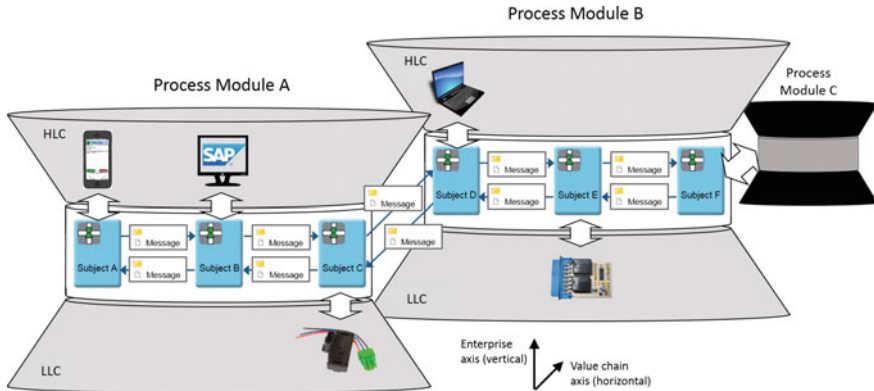


Fig. 3.10 S-BPM as a basis for horizontal and vertical communication in the automation diabol

(Vogel-Heuser and Feiz-Marzoughi 2013). The S-BPM based approach allows this module to be integrated as a “black box”, using the encapsulation concept enabled by subjects.

S-BPM facilitates changes in the communication model at design time and at runtime. This capability is enabled by the notational simplicity and modular composition of S-BPM models: Individual behaviours and data structures in a subject can be changed as long as the messages exchanged with the neighbouring subjects (and the business objects associated to these messages) remain the same. Messages can be viewed as interfaces between two subjects. There needs to be a realignment of the two subjects about the particular message, only if a change in a subject affects its message structure with another subject. Such a realignment may require further changes and realignments with other subjects. Yet, it can usually be expected that changes do not propagate to all the subjects of a model.

3.2 S-BPM’s Organizational Development Capabilities

Thinking in subject-oriented terms and modelling business processes in a subject-oriented notation aim to support overcoming the disruptive pressure organizations are currently facing (cf. Lorenz et al. 2015). In particular, it enables tackling how organizations should be dealing with changes at the same time when operating it. Transforming while performing requires a digital infrastructure, both in terms of human resources and technology, as the table from work practice reveals (Table 3.1).

Neither digitizing nor servitizing an organization through process integration can be handled simply by providing respective technologies. While technology is an indispensable enabler, such change processes require a human-centred approach, driven by management, one that takes the people who have to implement changes

Table 3.1 Shifts through digitization

	Traditional	Digital
Strategy	Efficiency	Innovation
Culture	Hierarchy	Collaboration
Talent	Low cost	High skill
Technology	Legacy	Cloud, mobile, apps
User experience	“Who cares?”	Mission critical
IT Philosophy	Waterfall	Iterative (agile)
Business model	Service and support	Relationship and partner

Source Michael Krigsman www.cxotalk.com. Available at: <http://techcrunch.com/2016/01/31/digital-transformation-requires-total-organizational-commitment/>

into account. So-called dynamic capabilities should enable building and reconfiguring internal and external resources including competencies (Eisenhardt and Martin 2000). The goal is resilient behaviour based on organizational agility (cf. Worley and Lawler 2010; Kirchmer 2011).

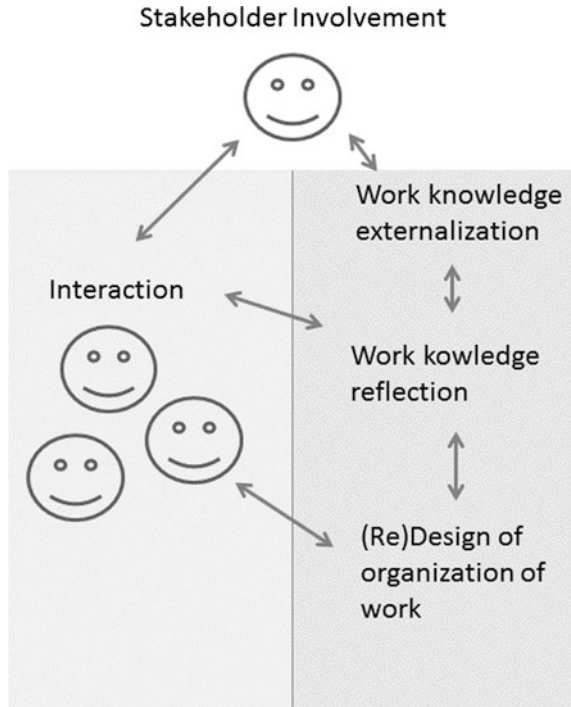
In change management projects IT-affinity tend to dominate (cf. Sambamurthy et al. 2003; Overby et al. 2006; Ngai et al. 2011; Kim and Suh 2012) although stakeholders¹ and their communities play a crucial role for succeeding in those projects. Korpelainen and Kira (2013) revealed “that most of the problems were identified in the social context and only one fifth of the problems were related to the employees’ experiences of a lack of skills and competencies in using the IT-systems”. Apparently, it still holds what Hammer (1996, 1999) found out already in the context of Business Process Re-Engineering when revisiting the original, model-centric concept of Hammer and Champy (1993).

Moving from adopting IT systems to organizational design involving human-centred work models and semantic process analysis (cf. Prilla et al. 2012) can be facilitated by business process modelling notations. Such a stakeholder-centred procedure needs to include the opportunity to transfer human experience and ideas into a process model for effective work support (Aschoff et al. 2003). Capturing work knowledge requires a context-sensitive BPM approach (cf. Ates and Bititci 2011; Silva and Rosemann 2012).

Following the human-centred approach for organizational development has a cognitive, a content-oriented and social perspective. From the cognitive perspective, a semantically valid representation of work knowledge is required when stakeholders create models and when eliciting/documenting work processes. From the content perspective, models represent the baseline of organizational development. From the social perspective, an intelligible and executable version of models is required. They allow sharing, reflecting and experiencing processes through different roles and stakeholders (Fig. 3.11).

¹Stakeholder denote humans directly or indirectly (e.g., being responsible) involved in business operations.

Fig. 3.11 Organizational development leveraging stakeholder knowledge



3.2.1 Creating Semantically Valid Representations

In this section, the acquisition of work knowledge from a stakeholder perspective, and its mapping to diagrammatic models is discussed. Existing concepts, stemming from Business Process Management (BPM) and Knowledge Management (KM) are reviewed. A conclusive summary wraps up the findings.

3.2.1.1 Work Analysis

Modelling principles and conventions (cf. GoM—Becker et al. 2008) traditionally set the stage for representing work knowledge in terms of process models. As in practice, modelling standards often comprise 100 and more pages, they may not be understood or accepted by stakeholders—a modelling notation should rather serve as a means for communication and sharing work knowledge than requiring technical mastery. The organizational aspect of work should be considered primarily from work profiles of stakeholders in the operational business, and the roles that need to be supported by information technology.

Often, stakeholders ask “What do I need an analysis for?” as they know their organization like their own pocket. However, process analysis moves beyond accumulating existing facts. Hence, it needs to involve all who could contribute to a work process. Analysis is an overarching process, which needs to involve a large

part of the organization, as it denotes a purposeful representation of relevant process information in preparation for transforming an organization (cf. Weske 2012).

Analysis may start with particular elements, e.g. with actors in S-BPM (Fleischmann et al. 2012) or functions as in ARIS (Scheer 1999). The context is framed by elements stemming from system analysis, knowledge management and organizational learning. Representations refer to a certain system, as they allow describing phenomena of various complexity (cf. Von Bertalanffy 1968). A major characteristic of a system is the set of mutual relationships as constitutive element. System thinking has been elaborated with respect to causal relationships and associative ones (cf. Senge 1990), as analysis targets identifying and describing besides the elements of a system their major effective relationships. The acquisition of work-relevant knowledge might include leveraging tacit or implicit knowledge (Nonaka and Von Krogh 2009). Explicit knowledge is already documented information whereas tacit knowledge is not available in documented form. It resides with people and can be elicited to explain the rationale of behaviours or processes.

In the course of analyses, performance-relevant processes among work force are put into mutual context. Traditionally, when the dynamic view of an organization is the focus, tasks rather than roles move to the centre of interest (cf. Scheer 1999). The essential question is how organizational units need to be mutually related to accomplish work objectives in a correct temporal order when executing tasks. Such arrangements should then be mapped to workflow specifications which are at least partially automated.

According to Fischermann (2006) purely task-centred approaches are likely to lead to some deficiencies with respect to stakeholder orientation: Positions located in managerial parts of the hierarchy are traditionally handling tasks with less cooperation, such as deciding on requests from the operational staff. However, running processes even in expert organizations, such as hospitals, requires effective and efficient collaboration. In addition, thinking in terms of processes is generally more difficult than thinking in familiar structures of a static organization of work.

A work process analysis is therefore a special form of organizational analysis. This means, conversely, that it should take into account the organizational structure in an appropriate way. The processes have to be aligned to the organization and to be embedded in existing hierarchical structures, leading to a process-oriented organizational hierarchy (Fischermann 2006).

S-BPM provides a twofold approach when analysing work procedures. One could either start taking a role-perspective and relevant communication acts among roles, or alternatively start to describe a certain encapsulated task behaviour and the communication interfaces to other behaviours (performed by certain roles).

3.2.1.2 Top-Down Versus Bottom-Up Modelling

In traditional process analysis basically two approaches can be followed, top-down and bottom-up: The top-down approach puts the corporate strategy and vision of an organization to the centre. Processes at the top level, such as customer service routines, are progressively detailed and structured. Process analysis is correspondingly understood as a stepwise refinement of the processes of a high-level

representation, such as value chains, to a more detailed description level, such as sequences of operational activities (Gaitanides 1983).

Both approaches to detailing a process, decomposition and refinement, leave open, at what level of detail processes need to be specified before starting refinements, and how to design the interface between different levels of detail. Different stakeholders will approach this issue in a different way (Fischermann 2006), thus, developing systematic guidelines is difficult. The analyst and the stakeholders involved in the collection and evaluation of data may interpret differently for each case, at what level of abstraction a process needs to be positioned.

In the bottom-up approach, however, processes are constructed from actions performed at a workplace upwards. As individual actions are linked to processes and procedures they propagate to various levels of abstraction. A survey could start identifying elementary actions involved in task accomplishment, and be followed by composing those actions to a process specification. The advantage of a bottom-up approach when involving operative stakeholders concerns the initial selection of an abstraction level, as it corresponds to their perception. Analysis will consequently lead to collecting and describing only those processes that match the perceived reality.

S-BPM promotes a bottom-up approach for eliciting and representing work knowledge. Bottom-up modelling in S-BPM may start with the definition of individual behaviours and their interfaces to inter-dependent behaviours. A next step could be the definition of exchanged data or the aggregation of subject behaviours to roles in organizations. The resulting models may be validated by domain experts in a role-play fashion supported via IT tools. The validation allows checking whether a created model meets the intended objectives or needs to be reworked.

3.2.1.3 Emergent Semantics

Most of the modelling approaches for work knowledge analysis provide a notation, which might be more or less oriented towards execution, such as CommonKADS (Schreiber et al. 2002) focusing on representation and analysis, and FRODO (Aschoff et al. 2003) interleaving modelling and execution of knowledge-intensive processes. Emergent semantic approaches allow dynamic development of semantic process representations. For instance, Cohn and Hull (2009) use (business) artefacts combining data and the manipulation process as basic building blocks of modelling. Artefacts are key business entities (business-relevant objects) evolving when passing through a business's operation. They can be created, modified and stored. As a result business operations can be decomposed along various levels of abstraction. Artefacts are typed using both an information model for data about the business objects during their lifetime, and a lifecycle model, describing the possible ways and timings that tasks can be invoked on these objects.

According to the approach, such an artefact could be a knowledge claim. Its information model could include attributes, such as claimID, originator, elaboration time, duration of validity, and operating information. The lifecycle model could include the multiple ways that the knowledge claim could be handled. Artefacts define a useful way to understand and track operations, such as the stations that a

claim has passed through, typically being of relevance for involved stakeholders. The information model's attributes are filled with information elements over the life cycle time of the artefact. In Cohn et al.'s approach (2009), artefact instances can be generated in state-based way, as instances interact through message passing as they transition between states. The artefact-based business operation model is thus being termed actionable. Specifications can be used to automatically generate an executable system based on various, accumulated kinds of data corresponding to the stages in a business entity's lifecycle. Clustering data based on a dynamic entity that moves through a business's operations is in contrast to decomposing business entities, as it avoids isolated data manipulations.

Moreover, it facilitates the use of representations, as the authors state "it enables strong communication between a business's stakeholders in ways that traditional approaches do not. Experience has shown that once the key artefacts are identified, even at a preliminary level, they become the basis of a stakeholder vocabulary. Artefacts enable communication along three dimensions" (Cohn and Hull 2009):

- Lifecycle dimension, as "stakeholders who focus on one part of a lifecycle are better equipped to communicate with stakeholders focused on another part. All are talking about the same overall artefact and can confidently discuss attributes that are shared or produced in one part of the lifecycle and consumed in another" (ibid.)
- Variations' dimension, as "stakeholders from multiple geographies could understand similarities and differences between their respective operations by comparing them to the commonly held artefact model" (ibid.)
- Management dimension: "Communication between stakeholders at different management levels is enhanced because the artefact approach naturally lends itself to a hierarchical perspective" (ibid)

Hence, we can conclude that evolving element and relation categories are of benefit for developing a stakeholder-oriented modelling and analysis approach (cf. also Salovaara and Tamminen 2009). The presented approach of Cohn and Hull (2009) may be mapped to S-BPM as follows: Data and their manipulation process map in S-BPM onto business objects and within certain subject behaviours. In S-BPM, there is not an overall defined data manipulation process, instead data may be changed by different subjects depending on the defined "create-read-update-delete" operations for the dedicated subject (operation). Finally, an S-BPM model defines the exchange sequence of data embodied in certain message exchanges.

3.2.1.4 Semantic Business Process Management

Semantic Business Process Management (S-BPM) relies on ontological concepts in order to capture process-relevant items, however, targeting at automated processing and reasoning (Ciuciu et al. 2011; de Castro et al. 2010; Hoang et al. 2010). While striving for consistency by relying on a common terminology, "the main challenge here lays in the availability and existence of the common domain description that would be accepted by the process participants. Not only obtaining process

participants' acceptances to use the proposed ontology that constitutes a problem, but also development of domain ontologies that would be a specialization of already delivered solutions is a challenging and time consuming task" (Filipowska et al. 2011).

In a first phase in S-BPM a business analyst models a business process. As a result of this phase, semantically annotated business process models exist. They should not only capture explicitly the functionality of tasks and decisions in the process flow, but also actors, roles, resources that are involved in the process. This process content is revisited in terms of not only modelling, but also with support of ontologies in terms of additional functionalities taking advantage of the ontological process descriptions (e.g. ontology-based searching for process fragments matching business criteria, process fragments reuse or compliance checking). This design reflects a set of activities supporting stakeholder needs in analysis, which have to be captured methodologically (cf. Mendling et al. 2010).

3.2.1.5 Conclusive Summary

What kind of support could stakeholders need when getting involved actively in organizational development based on work processes? The current findings indicate that

- Eliciting knowledge requires an open format for articulation and collaborative reflection (semantic openness). Hence, predefined notations could direct articulating work knowledge and inputs for change in a certain direction, e.g. functional representations, role-based representation
- Knowledge codification needs to be accompanied by sharing knowledge. It needs to be accessed and reflected by others—representations, such as concepts or business process models serve as baseline for discussion and discourse
- Middle-out as well as top-down analysis should be performed on models, depending on the type of granularity and encapsulation
- Intertwining the functional perspective on accomplishing tasks with interaction processes helps not only for reflecting a situation "as-it-is" to come up with ideas "as-it-could-be", but also for setting the context of work procedures in terms of relevant factors for task accomplishment

3.2.2 Process-Based Organizational Development

Both developers and stakeholders need to be qualified for effectively participating in work (re)design, in particular when innovative concepts need to be handled (cf. Lorenz et al. 2015 for industry 4.0). As indicated also above, openness for content generation and sharing seems to be crucial for stakeholder-driven organizational development: "Incremental innovations and organizational learning processes are of growing importance for the competitiveness of firms" (Strambach 2001, p. 56). For flexible operation, stakeholders have to work on their work

processes (Herrmann 2000; Herrmann et al. 2004), rather than being qualified to adapt (cf. Pütz and Lüger 2003).

The more stakeholders are informed about their organization of work, the more they become connected personally to their performance, and finally, willing to change (cf. McGregor 2006). It has been observed that people react to situations based on context rather than fixed behaviour patterns, such as process specifications they need to follow (cf. Meyrowitz 1985). Hence, even roles as functional or social entities evolve over time (Castells 2010). Stakeholders may change roles dynamically, driven by their personal identities triggering their behaviour (cf. Montague 2012). Such observations manifest individuals as self-regulated subjects. As such, they decide according to the construction of their reality on goals and the arrangement of activities. Based on their conscious reflection, they learn to select from a variety of options to act, and finally, to solve problems (cf. Edelmann 2000).

Consequently, any approach to organizational development should allow active design when organizing work and be on some characteristic particularities, according to Ulich (1991) (cf. Arnold 1996; Sennett 2008): (i) holistic, (ii) challenging, (ii) possibility of social interaction, (iii) featuring autonomy, (iv) facilities to learn and develop. Organizational development driven by actively engaged actors mainly concerns work and business processes (cf. Fischer 1989). Once stakeholders reflect work practices, self-transforming of organizations is enabled (Geißler 1995; Seidl 2005). Thereby, the direct access of actors to organizational development knowledge, including the business processes stakeholders are actually involved in, seems to be essential (cf. Schwaninger 2000).

From management theory, timely organization of work has already been recognized as learning endeavour, depending on highly engaged stakeholders (cf. Rieckmann 1997). However, few implementations of organizational development concepts exist focusing on the highly dynamic nature of business structures and learning facilities that need to be provided for engaging stakeholders in the above mentioned sense. Although a variety of frameworks exist for systemic organizational change (cf. Senge 1990; Kim 1993; Haeckel 1999) they mostly lack operational support (cf. Zhu 2009).

According to Chen et al. (2003) systems supporting organizational change should comprise the following: (i) an integrated Organizational Memory, (ii) individual learning support on the operational and conceptual level, (iii) lower and higher level organizational learning, (iv) an organization-wide Knowledge Management System (KMS). In case of BPM-driven organizations business process models are part of the organizational knowledge that needs to be kept as organizational asset. In addition, information about process analysis, validation, implementation (workflow management) and optimization needs to be kept.

Operational learning by individual stakeholders should be supported enabling direct access to the Organizational Memory, while individual conceptual learning requires integrated ICT-support for communication, content management and dissemination. Lower level organizational learning refers to adjustments of processes to their environment, e.g. through establishing additional lines of dissemination, whereas higher level organizational learning affects mental models, and as such

underlying assumptions and beliefs influencing thinking and behaviour in work processes. These assumptions rely on fundamentals, such as knowledge about BPM and its practical implementation through Workflow Management Systems.

Individual learning support on both levels requires education qualifying stakeholders for their engagement in (BPM-based) organizational change. Besides *epistemological* connections, *personal* connections to BPM knowledge need to be provided for stakeholders actively engaging in learning processes (cf. Resnick et al. 1996). Facilitators to this respect are personalized learning environments (cf. Dabbagh and Kitsantas 2012), social technologies integrated in BPM lifecycle support systems (cf. Matthiesen et al. 2011), and agility support features (Bruno et al. 2011).

For S-BPM the main qualification need is given for modelling. The qualified participation in S-BPM organizational development projects to fully utilize S-BPM's human support capabilities is twofold.

- *Diagrammatic skills*: On one hand Subject-Interaction Diagrams need to be understood as primary means of abstracting from behaviour in a certain situation, e.g. state of organizational development. On the other hand, each subject needs to be refined to concrete actions.
- *Perspective skills*: Subject-specific activities comprises two perspectives on the same behaviour abstraction: first, functional role behaviour, and second interaction with other subjects (sending and receiving messages). The latter is substantially important to accomplish a model of how to run an organization.

For executing S-BPM specifications, the validation phase reveals semantic and syntactic correctness. The subsequent execution allows for direct user experience before freezing procedures for the actual business operation until the next cycle of organizational development is triggered.

3.3 S-BPM's Human Support Capabilities

Chapter 2 revealed that humans will remain a vital element of future production situations and need to be involved in organizational development efforts and continuous workplace improvement. Thereby, human-centred design techniques and the involvement of domain experts contribute to people-centred workplace design. Furthermore, organizational structures and workflows shall be designed to support the empowerment of organizational actors and high involvement in workplace redesign and continuous improvement. With respect to human support capabilities, S-BPM offers different potentials such as:

- Eliciting process knowledge of domain experts
- Involvement of domain experts in process design
- Development of a shared process understanding between domain experts

- Workflow execution support
- Workflow monitoring and analysis (e.g. via KPIs, reporting).

The first three bullets target designing work practices. The last two bullets aim at run-time support for actors (manager, worker, etc.) of organizations. Subsequently, the potential of S-BPM and a possible enrichment for designing industrial workplaces in a human-centred manner will be illustrated. Beyond, run-time support that can be offered by S-BPM implementations will be discussed.

3.3.1 Designing Industrial Workplaces in a Subject-Oriented Way

Subject-oriented business process management (S-BPM) aims to provide simple tools for people when designing and improving their own workflows. As it has been successfully used in many office-based business processes such as credit applications and order processing (Konjack 2010; Nakamura et al. 2011; Walke et al. 2013), the addressed processes are predominantly virtual—they are executed almost entirely within IT-based environments using various software tools such as SAP, Microsoft Office and email programs. As a result, business processes can be specified without much information related to the physical, cultural or social environment in which they occur—they can often be executed independently of the spatiotemporal location of the involved or concerned people.

However, more detailed information about the context is crucial in the physical world of production processes where the spatial layout of workplaces in the factory, the artefacts and tools available, the work culture and the company values embody a specific way of working that may be different from the desired processes. Successful factory and workplace development creates a way of working that employees want to adopt. This can only be achieved once there is no mismatch between the planned interactions people are to perform to achieve their personal and company goals, and the actual interactions afforded by the people's work context (Vilpolá et al. 2006).

What could an enhanced S-BPM methodology look like for improving workplaces considering both people-centred and economic aspects? One way to derive such a methodology is to examine existing approaches for each aspect and check whether they could contribute extending the current S-BPM methodology (cf. Table 3.2). Typical approaches for the two aspects include contextual design (emphasizing people-centred aspects) and value stream design (emphasizing economic aspects). However, we first look at the existing S-BPM methodology. Its steps include (Fleischmann et al. 2012, p. 29ff):

1. Analysis: defines the scope and goals of process improvement and sets up a project structure
2. Modelling: represents the process in terms of the subjects (i.e. the active entities in the process), their interactions and behaviours, and the data handled by them

3. Validation: checks whether the process is effective
4. Optimization: checks whether the process is efficient
5. Organization-specific implementation: integrates the process in the organization by assigning people and departments to subjects
6. IT implementation: integrates the process in the organization's existing IT infrastructure
7. Monitoring: executes the process and collects data from it for evaluation and, potentially, a further cycle of improvement

Contextual design is based on observing how the work unfolds, directly at the workplace. This allows gathering ongoing experience about the people's work, how processes are managed and systems are used, rather than relying on abstract information. While contextual observation or inquiry aims at capturing the workers' subjective views of their context (Kannengiesser et al. 2014), this method uses an external consultant who observes and asks questions related to the reasoning behind some of their actions. The consultant documents these observations using notes, sketches and sometimes photos to facilitate the identification and documentation of problems or "disturbances" from the perspective of the worker. The detailed steps of contextual design are described in (Beyer and Holtzblatt 1998; Bonaldi et al. 2011) and include:

1. Contextual Inquiry is conducted with users in their workplace while they work, observing and inquiring into the structure of the users' own work practice. Data is collected through observations and interviews and is validated through team interpretation sessions.
2. Work Modelling: Five work models capture the work of individuals and organizations in diagrams. Each model provides a different perspective on how the work is done.
3. Consolidation refers to the process of defining a common pattern and structure without losing individual variation.
4. Work Redesign uses the consolidated data to focus the conversation on how technology can help people accomplish their tasks. The redesigned work is captured in scenarios embodied and elaborated upon in storyboards.
5. User Environment Design captures the "floor plan" and design of a new system, how each part of the system supports the users' work – along with what functions are available in it – and how to access each of these parts.
6. Mock-up and Prototype Testing are important to system development in ensuring functionality and usability. Furthermore, continuous iterations of prototyping and testing have the potential to bring incremental improvement to the system and drive detailed design (Bonaldi et al. 2011, p. 99).

Scoping typically comprises all activities related to the definition and qualification of the object (e.g. workplace, tool, process) to be (re-)designed. Scoping comprises collecting data, gathering requirements and defining the scope based on the collected information. In order to collect information (*Collecting*) different elicitation techniques such as workshops, focus groups, creativity techniques, interviews, document analysis or product analysis may be applied. In SO-PC-Pro, the focus on collecting data from the people involved has been considered vital.

Table 3.2 Methodological design framework synthesis based on S-BPM, contextual design and value stream design (output-oriented mapping)

Extended methodology	S-BPM	Contextual design
1. Scoping	Analysis Goal of process analysis, initial information	Involved processes, people, customers, products, timeframe, available resources
2. Collecting workplace information	Monitoring and analysis AS-IS situation described in terms of: Who acts? What is done? What is edited? Process metrics, AS-IS: Existing process models, process instances, key performance indicators	Workplace observation data, Interview data revealing relevant aspects of the workplace
3. Representing workplace information	Modelling Subject Interaction Diagram, Subject Behaviour Diagram, Business Objects	Flow Model, Sequence Model, Physical Model, Artefact Model, Cultural Model -> revealing relevant aspects of work that matter for the design and existing disturbances
4. Consolidating workplace information	Modelling views, remarks of process participants related to process models	Individual views, remarks of stakeholder (customer, user) related to work-relevant dimensions
5. Synthesizing improved workplaces	Validation, optimization To-be model, validation results, adapted to-be model	Vision statement, storyboard
6. Prototyping	Integration UI-prototypes, process prototypes	Paper prototypes, documentation of user interface ideas
7. Implementation	Integration Actor definition, role specification, assignment of actors to roles, integration with existing IT-systems	NA

However, in order to be able to communicate and align different views on workplaces representations are required.

Representing Workplace Information depends on the scope and may include contextual models, value streams or subject-oriented process models as means for communication, *consolidation* and *alignment* of different views on a workplace. The structured and aligned representation of workplace information provides the basis for *Synthesizing Improved Workplaces*. Synthesizing comprises the design and validation of (new) solutions ideas (e.g. new process design and immediate validation via IT-supported role-play; design of to-be physical model and validation of the model with workers; to-be value stream map; Storyboard).

For selected design solutions prototypes should be built, in order to allow to get feedback from involved users at an early stage of development. **Prototyping** can comprise process prototypes, UI-Prototypes, tool prototypes or even workplace prototypes to test real-life work settings. Prototyping results inform the (organizational and technical) *implementation* of desired solutions.

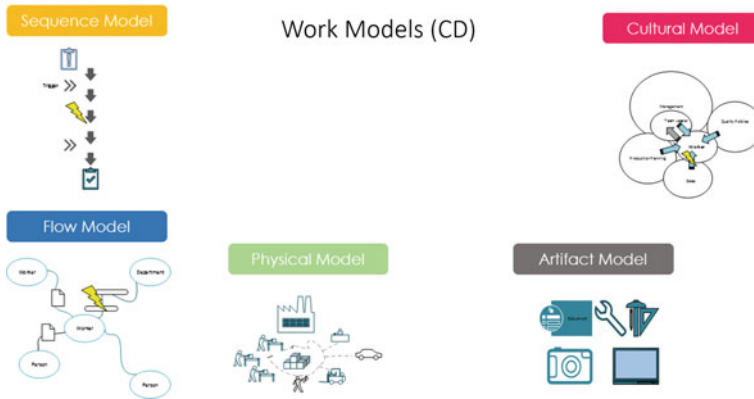


Fig. 3.12 Work models used in Contextual Design

An enrichment of S-BPM models with context information to be able to support contextual design has been presented in Bonaldi et al. (2011). In the contextual design approach, this information is captured in five “work models” showing different aspects or dimensions of the work context (Beyer and Holtzblatt 1998; Holtzblatt and Beyer 2014). Conceptual depictions of the five Contextual Design work models are shown in Fig. 3.12.

The different models have been described in the literature (Beyer and Holtzblatt 1998; Holtzblatt and Beyer 2014). Various information elements could be derived from published examples (Beyer and Holtzblatt 1998; Holtzblatt 2001; Holtzblatt et al. 2005; Vilpolo et al. 2006), and enriched with work on modelling context in business process management (Saidani and Nurcan 2007; Rosemann et al. 2008; Heravizadeh and Edmond 2008). The SO-PC-Pro development team derived several information elements for each model:

1. *Flow model*: This model captures the *communication/information* dimension of workplace context. It includes the following information elements:

- Role (formal or informal), e.g. assembly line worker, care-taker
- Task (to describe responsibilities of a role, e.g. assemble part, discuss safety issues)
- Object (e.g. work bench, shipping document, receipt)
- Communication/collaboration relation (between roles)
- Generic relation (between roles, objects)
- Disturbances (problems, e.g. related to communication, tasks, objects)

2. *Sequence model*: This model captures *activity* dimension of workplace context. It includes the following information elements:

- Organizational role
- Activities and their sequence

- Intent of activities
- Trigger
- Event
- Time/duration
- Disturbances (problems)

3. *Physical model*: This model captures the *environment* dimension of workplace context. It includes the following information elements:

- Movements (e.g. direction, speed, route)
- Places/locations
- Physical objects in the environment
- Environment characteristics (e.g. light, humidity, noise)
- Map/floorplan
- Disturbances (problems)

4. *Artefact model*: This model captures the *tool/document* dimension of workplace context. It includes the following information elements:

- Documents
- Structure of documents
- Tools (incl. physical and software tools)
- Information structure
- Disturbances (problems)

5. *Cultural model*: This model captures the *social/cultural* dimension of workplace context. It includes the following information elements:

- Dependencies (e.g. hierarchical relations, perceived influences/expectations)
- Stakeholders
- Personal factors (e.g. physiological, mental, mood, expertise, stress, health, cultural and personal values)
- Disturbances (problems)

Some of the information elements contained in the Contextual Design work models can be associated as annotations with specific modelling elements of S-BPM, thus enriching process information with context. Furthermore, information elements from Contextual Design work models may be (partially) mapped to S-BPM modelling elements as described in the subsequent sections.

S-BPM modelling elements partly overlap with Contextual Design work models and may be used in order to represent Flow models and Sequence models. Following, a mapping for both model types to S-BPM elements is given in Table 3.3. In this table, a checkmark indicates the overlapping of the constructs in S-BPM diagrams and the Contextual Design Flow Model.

Roles of Flow Models may be represented in Subject Interaction Diagrams as subjects. Subjects represent a behaviour in a process and can be executed by a person or technical system (i.e. actor). S-BPM also defines “role” as basic modelling construct. In S-BPM, a role aggregates multiple subject behaviours and links concrete actors with subject behaviours. However, existing modelling support tools do not aim to graphically depict roles in Subject Interaction Diagrams. Roles are configured separately as properties of subjects. The representation of tasks for a role in Flow models may be depicted in a Subject Interaction Diagram as textual annotation for a subject. Tasks of a role within a concrete process could also be represented as functions (do, send, receive) in Subject Behaviour Diagrams. However, for an initial high-level model comprising roles, their interaction and tasks of a role, it is recommended to model tasks as textual annotations.

Objects (e.g. shipping document, receipt) of Flow models may be represented using the corresponding S-BPM modelling element “business object”. Communication Relations of Flow models may be represented in Subject Interaction Diagrams as message flows. Regarding message flows, S-BPM offers the possibility to depict the message name and the objects (e.g. documents, forms) that are exchanged between subjects. Generic Relations between subjects are not part of the language definition. In order to include this information in S-BPM models, the respective subjects can be annotated with reference to the according Contextual Design work model showing these generic relations.

In Flow models flash symbols are used to indicate disturbances related to roles, tasks, relations or objects. Equivalently, a modeller may use yellow or red flags to indicate such disturbances related to the given modelling elements. Subsequently, a Flow model created with Metasonic Suite is depicted in Fig. 3.13 to illustrate the defined mapping given in Table 3.3. The model comprises four different subjects: Technologist, Production manager, Worker, Quality Control. The Technologist handles customer orders and defines required operations, estimated times for each production step and the required blueprint. In case a CNC programme is required, the technologist writes the programme after a request from the worker. Problems for the Technologist arise related to the time estimations for certain operations. They are considered unrealistic by the workers. This disturbance is indicated through the red flag number 1 in Fig. 3.13. Further disturbances are indicated related to the task “prepare workplace” which is performed by the worker (cf. flag number 2). In this case required tools and materials are regularly not available. A third disturbance is depicted related to the object “produced part” (cf. flag number 3)—some parts are lost in the shop floor and the reason has not been identified so far.

Sequence models from Contextual Design focus on the *activity* dimension of workplaces. Activities and their sequences are depicted in S-BPM for each subject separately within a Subject Behaviour Diagram. In the following, Table 3.4 depicts a mapping of modelling constructs defined in Sequence Models and Subject Behaviour Diagrams.

Table 3.3 Mapping Flow Model elements to S-BPM Subject Interactions Diagram constructs

S-BPM constructs	Subject Interaction Diagram	Contextual design— <i>Flow model</i>				
		Role	Task	Object	Communication relation	Generic relation
	Subject Interaction Diagram	Internal subject	✓			
		External subject	✓			
		Message flow			✓	✓
		Message			✓	✓
		Business object		✓	✓	✓
	Additional (semantically open) annotation elements	Flag				✓
		Rectangle				✓
		Circle				✓
		Triangle				✓
		Text annotation	✓			✓

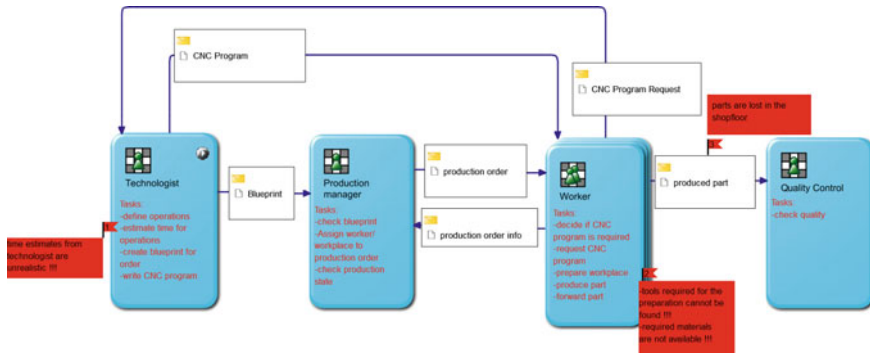


Fig. 3.13 Example mapping of a Flow model to a Subject Interaction Diagram

Sequences in Subject Behaviour Diagrams are either triggered by specific states (start states) or receive states. To indicate the intention or purpose of an action, textual annotations on states or flows may be defined. Events may be modelled as receive or send states. Activities are equally to function states in Subject Behaviour diagrams. The sequence of activities may be represented as sequence or message flows. Regarding disturbances, a modeller may use annotation elements to indicate problems related to the modelling elements. Following, the behaviour of the technologist represented in the Flow model in Fig. 3.13 is depicted in Fig. 3.14. The internal behaviour is enriched using textual annotations for INTENT and TRIGGER. Furthermore, red flags are used to indicate disturbances.

The mapping of both, flow models and sequence models from Contextual Design to S-BPM modelling constructs is intended to show the feasibility of using S-BPM as alternative for these models. As an advantage S-BPM models provide the capability to immediately validate the communication and coordination among subjects via IT-supported role-plays. Furthermore, the modelling and implementation effort related to an executable workflow can be significantly reduced, since S-BPM models can serve as basis for generating the required software.

As described above, Flow models and Sequence models from Contextual Design can be mapped to Subject Interaction and Subject Behaviour Diagrams. For the remaining diagrams a direct mapping requires additional effort, since Artefact models, Physical models and Cultural models focus on different information categories. Some information elements within these models can be modelled as attributes of existing S-BPM modelling elements, adding valuable contextual details. Other information elements can be seen as being subsumed in existing S-BPM modelling elements. An overview of S-BPM elements and their definitions, and the subsumption and extension relationships with contextual information elements is shown below (Tables 3.5, 3.6, 3.7, 3.8, 3.9 and 3.10).

Table 3.4 Mapping Sequence Model elements to S-BPM Subject Behaviour Diagram constructs

S-BPM constructs	Subject Behaviour Diagram	Contextual design—Sequence model				
		Intent and purpose of action	Trigger	Event	Activity	Sequence
	Subject Behaviour Diagram	Start state	✓			
		End state				
		Function state			✓	
		Receiving state		✓		
		Sending state		✓		
		Sequence flow				✓
		Message flow				✓
	Additional (semantically open) annotation elements	Flag				
		Rectangle				✓
		Circle				✓
		Triangle				✓
		Text annotation	✓			✓

INTENT: Create a feasible blueprint for a production order from a customer which can be effectively and efficiently produced on the shopfloor

TRIGGER: Customer order

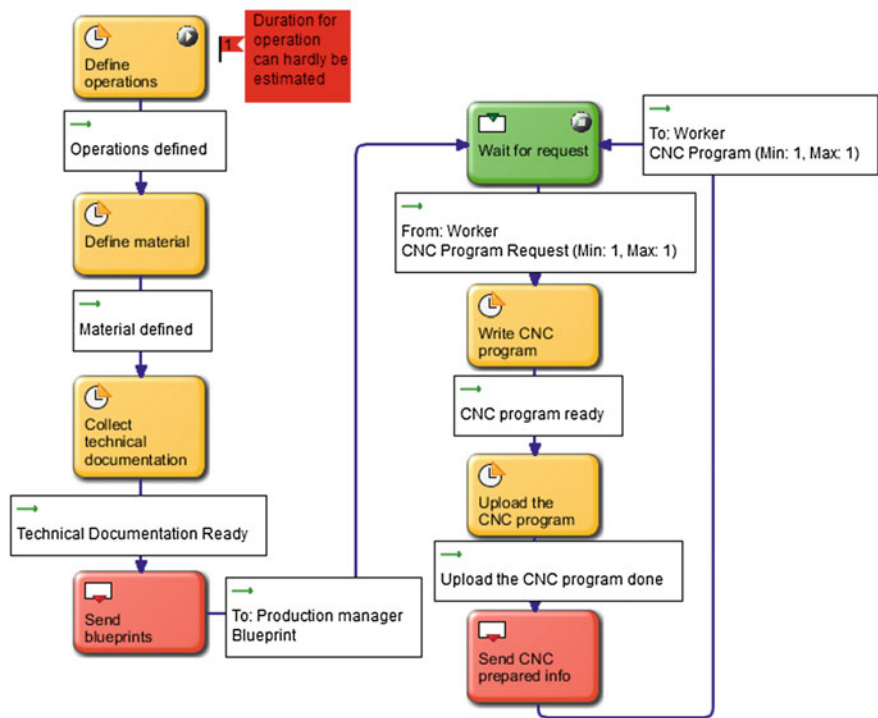


Fig. 3.14 Example mapping of a Sequence Model to a Subject Behaviour Diagram

Table 3.5 Subject definition and contextual information subsumption/extension

A subject is a process-related functionality to be executed by an actor		
subsumes:		is extended by:
• Responsibility		N/A
• Intent (in a sequence model: what is the overall goal/functionality of the set of activities)		

Table 3.6 Role definition and contextual information subsumption/extension

A role is an organizational position aggregating multiple process-related functionalities (similar to a “job description”)		
subsumes:		is extended by:
• Role		N/A

Table 3.7 Actor definition and contextual information subsumption/extension

An actor is the person or technical system executing a subject	
subsumes: <ul style="list-style-type: none">• Individual	is extended by: <ul style="list-style-type: none">• Expectations, needs, values, wishes, strategies• Influences between actors (cultural/social) Disturbances

Table 3.8 Message definition and contextual information subsumption/extension

A message is a piece of information exchanged between subjects	
subsumes: <ul style="list-style-type: none">• Communication	is extended by: <ul style="list-style-type: none">• Location of the communication• Disturbances, disruptions

Table 3.9 Business object definition and contextual information subsumption/extension

A business object is a data structure that is created or edited by a subject. It can be associated with a message to be passed from one subject to another	
subsumes: <ul style="list-style-type: none">• Artefact (as abstract, virtual representation of information)	is extended by: <ul style="list-style-type: none">• Physical representation of the business object: structure, layout, texture, colour etc. of documents or other objects• Physical interaction with the artefact (affordances)• History of affordances (How was it used previously? How is it used now?)• Disturbances

Table 3.10 State (being part of subject behaviours) definition and contextual information subsumption/extension

A state is the activity in which a subject can engage. There are three types of states: function states (“what do I need to do”), receive states (“what do I receive from another subject”), and send states (“what do I provide to another subject”). States are interconnected by transitions	
subsumes: <ul style="list-style-type: none">• Steps• Sequence, loops, branches• Trigger/event (subsumed by a message being received)	is extended by: <ul style="list-style-type: none">• Intent of individual states• Location of the behaviour and its physical environment• Physical description of activities and interactions with objects• Tools used for carrying out the activities (hardware, software)• Disturbances

3.3.2 Designing and Executing Organizational Structures for Active Involvement and Empowerment of Organizational Actors

Aside from applying S-BPM as means to elicit context-sensitive workplace knowledge and to develop a shared understanding and alignment among workplaces, S-BPM models can be developed fostering the involvement and empowerment of people in organizations.

The notion of people-centeredness is generally viewed as a particular characteristic or quality of a production workplace, describing a state in which the physical, sociocultural, operational and economic workplace environment is closely aligned with the needs of the people working in that environment. Striving for such a state is the goal of any production company concerned about the well-being of its workers. Thus, people-centred technologies should aim to support this quest based on a view of people-centeredness as a process rather than a state of affairs. Such a view takes into account the dynamics of both the production environment and the worker's needs. Workplaces need to be continuously adapted to make people-centeredness truly sustainable rather than the result of a one-off improvement project.

One effect of this view is that changes need to be considered as first-order citizens of a people-centred workplace. Changes can be related to various aspects (e.g. the physical work environment, work procedures and instruments) and may occur at different levels, e.g.:

- The requirements level: relating to changes in the environment impacting the company, including external (e.g. new legislation or competitive environment) and internal influences (e.g. novel company policies)
- The model level: relating to changes in (normative) descriptions of workplaces, including process models and (possibly) associated contextual information
- The instance level: changes in resources or running instances of a process

Changes rarely occur in isolation. A single change can trigger a set of other changes (at model and instance level) that need to be taken into account. *Change propagation analysis* aims to investigate how a local change (occurring at requirement, model or instance level) can lead to other changes and to checks whether existing constraints, rules or the structural and behavioural soundness of processes are violated (Rinderle et al. 2004; Fdhila et al. 2015). For instance, many workplace improvement suggestions provided by workers are not limited to a single workplace or worker. When sharing information about the work context, tools and interactions with other workers, it is often the case that a suggestion made by a worker also affects his/her co-workers. Similarly, when changes occur in real-life process executions, it is very likely that the model has to be adapted as a consequence, e.g. to avoid the violation of constraints such as norms for quality assurance.

A prerequisite for change propagation analysis is the identification (or “acquisition”) of initial local changes. For the purpose of suggestion and idea collection, people in a company pose a valuable source of information as they can be considered domain experts in their field of activity (cf. Fairbank and Williams 2001; Setiawan et al. 2011). Research in the fields of employee involvement and empowerment suggests that the involvement of people in organizational innovation processes has the potential to lead to substantial improvements and financial benefits (cf. Fairbank and Williams 2001). However, adequate organizational structures and tool support for collecting suggestions and evaluating them is required (cf. Fairbank and Williams 2001).

Collecting local changes, suggestions or errors require a collective effort engaging workers who contribute their suggestions for workplace enhancement, as well as collaboration when keeping track of the actual data to be analysed for detecting changes. Collecting input for change propagation and impact localization analysis thus need a *collaborative environment* in which issues, suggestions and process data can be collected, shared and discussed with others. In this regard, S-BPM processes may be designed to digitize “Suggestion making processes”, “Error reporting processes” and to provide basis for change propagation analysis. The case presented in Chap. 5 will describe the design and implementation of such an endeavour at an Italian SME.

3.4 Conclusive Summary

The aim of this chapter was to investigate capabilities and potentials of the S-BPM application within the context of future production systems. Thereby, taking the socio-technical system perspectives (introduced in Chap. 2) has been continued and the potentials and capabilities are structured along the dimensions technology, organization and human.

Recent technological developments in the field of S-BPM target towards process integration among different levels of control. Section 3.1 presents the traditional automation pyramid and S-BPM prototypes that allow for integration across different levels of control. Aside, this section presents an innovative approach to system integration in production companies based on the so-called automation diabolio. In this context, S-BPM can act as middleware exhibiting the communication model between different system participants.

Since technology only serves as enabler for better workplace design, additionally, requirements stemming from organizational development have been revisited and discussed with respect to the S-BPM approach in Sect. 3.2. In this regard, S-BPM may serve to represent and (partially) automate work practices in a bottom-up manner. Thereby, the involvement of domain experts/users is emphasized in order to empower people to become active workplace redesigners and tailor solutions to dedicated workplace requirements.

The potential of S-BPM to support humans in organizations has been discussed twofold. On the one hand, the enrichment of the S-BPM approach with contextual design elements aims to provide a comprehensive approach to capturing and designing work practices in production industries. On the other hand, S-BPM enables designing organizational structures that foster active involvement and the empowerment of people as discussed in Sect. 3.3.2.

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